



A Framework for Seamless Prediction

Jim Kinter

CFSv3 Planning Meeting

College Park, MD

25 August 2011

Why Seamless?

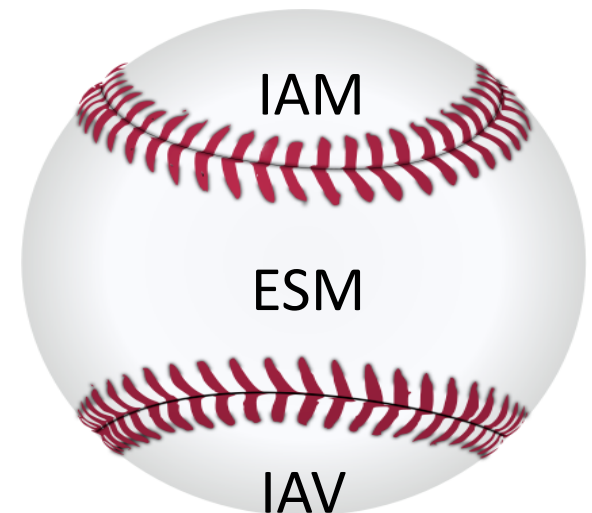
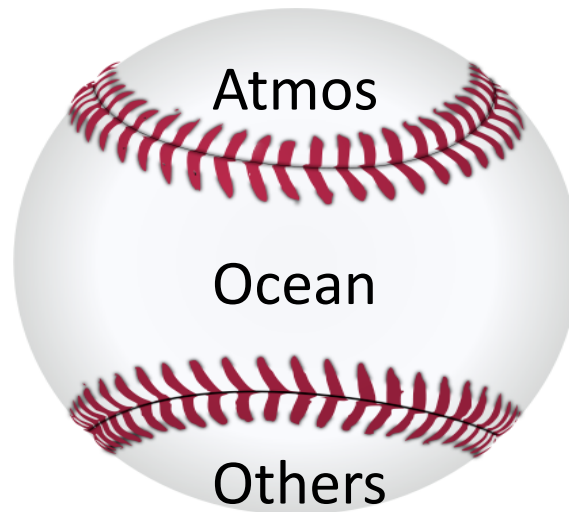


Sometimes seams are necessary ...

Why Seamless?



Sometimes seams are a bad idea!



Why Seamless?

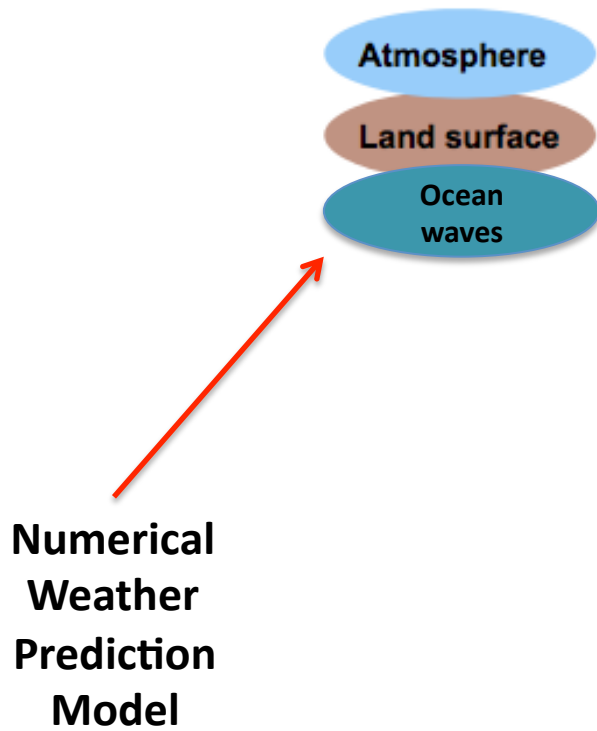
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Drivers

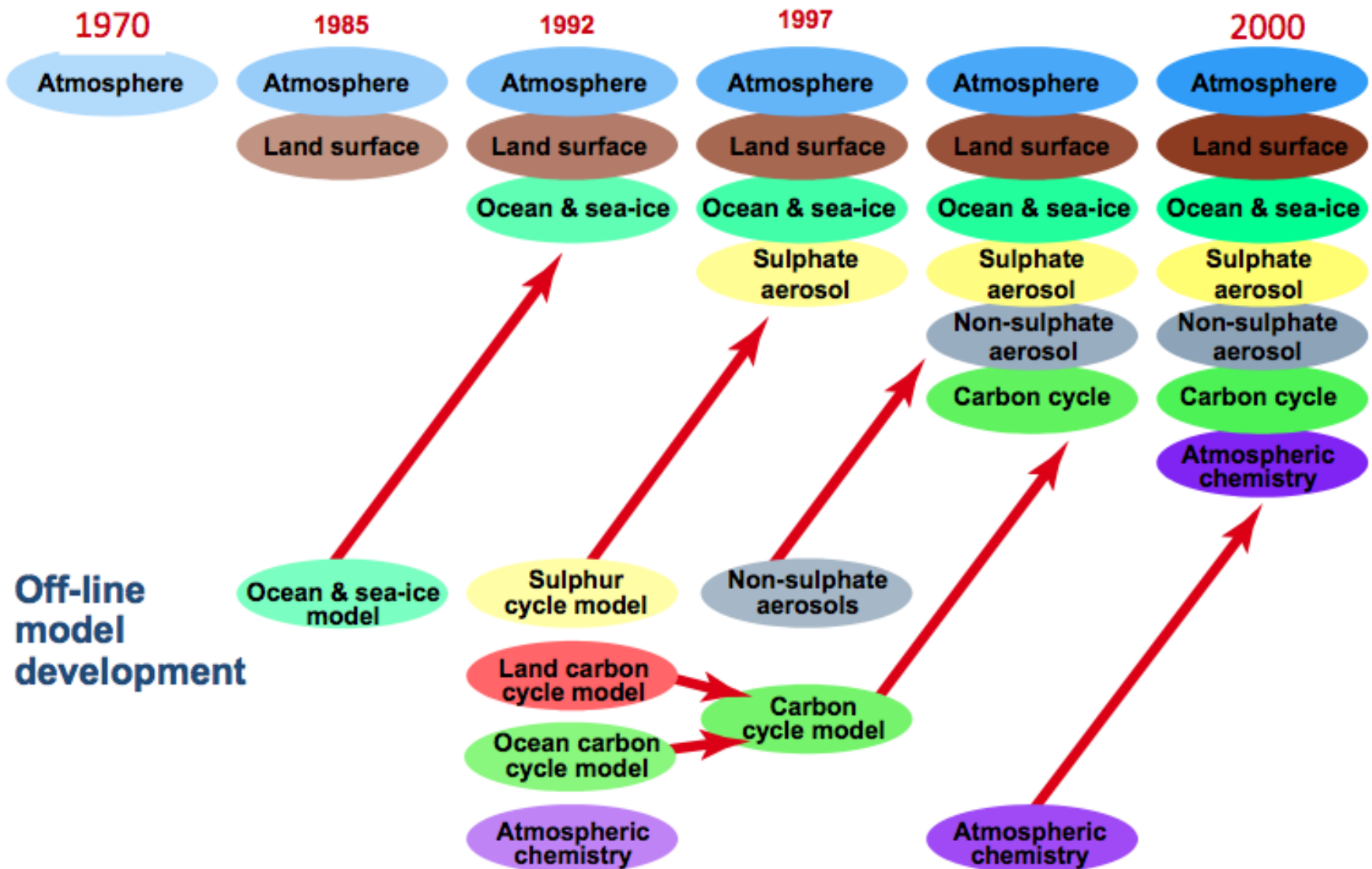
- User demand
 - Timely, accurate weather forecasts, ISI climate outlooks, decadal predictions and climate change projections
 - Reduced uncertainty
 - More products appropriate to particular applications
- Observing systems
 - Weather observations as source of climate data records
 - Climate-length records to inform model development (reanalysis)
- Model development
 - Fast processes important for both weather and climate
 - Increasing recognition of oceanic role in weather
- Computing
 - What will we do with the next 1000X computational capability?

Research Issues

- Earth system model development



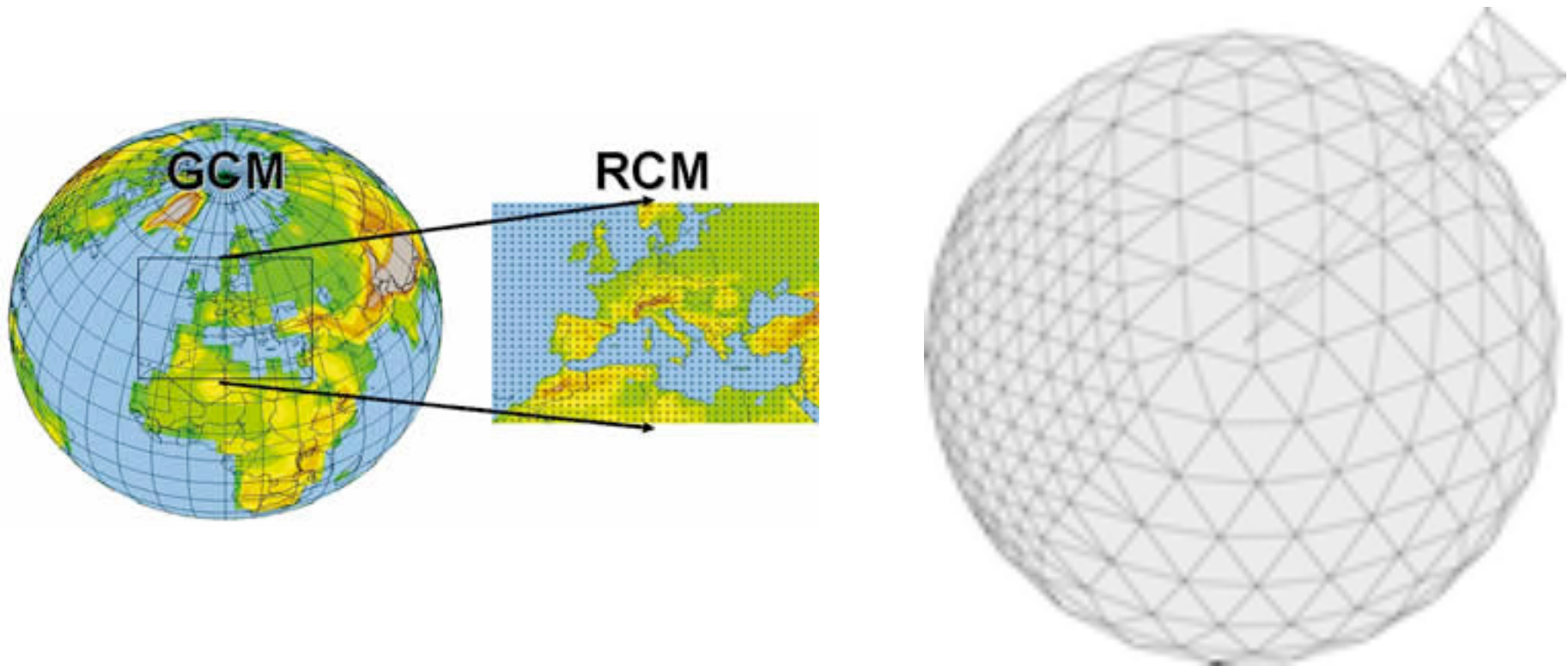
Towards Comprehensive Earth System Models



Research Issues

- Earth system model development
- Process-resolving model development
 - Regional domain models vs. global models (mesh refinement)

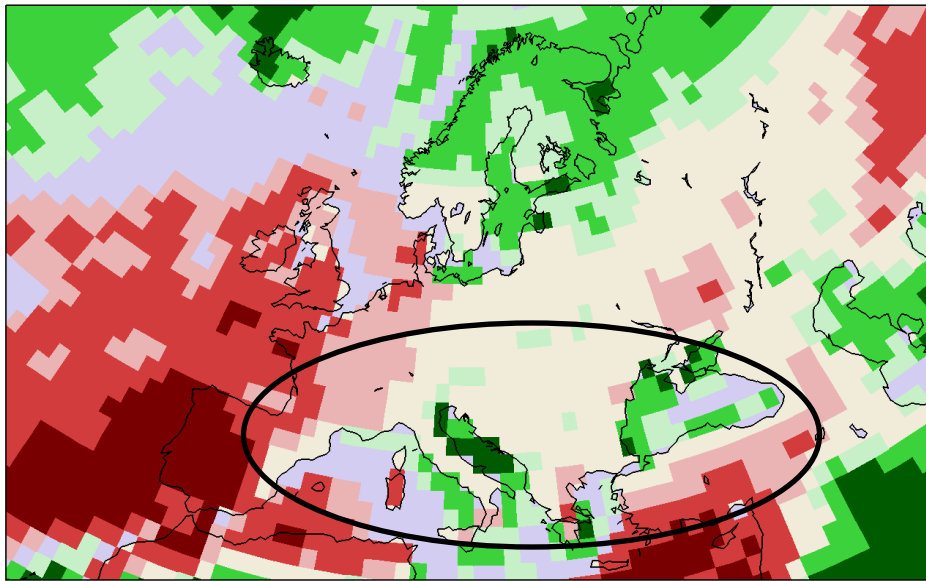
Regional Climate Model vs. Global Model Mesh Refinement



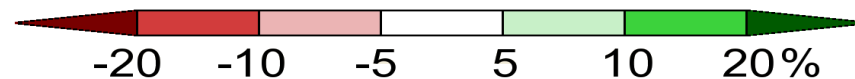
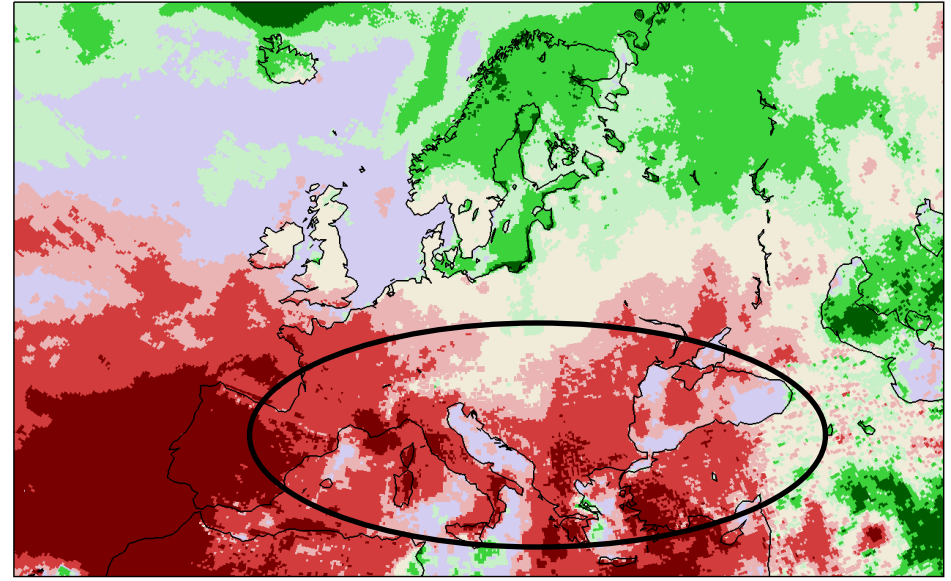
Growing Season Mean Precipitation Change

Europe: Apr-Oct 21st C minus 20th C

T159 (125-km)



T1279 (16-km)



“Time-slice” runs of the ECMWF IFS global atmospheric model with observed SST for the 20th century and CMIP3 projections of SST for the 21st century at two different model resolutions

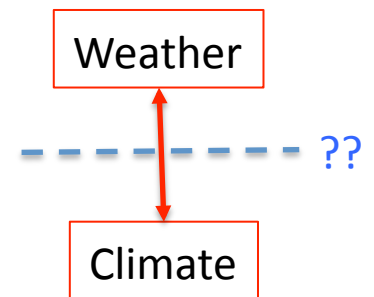
The continental-scale pattern of precipitation change in April – October (growing season) associated with global warming is similar, but the regional details are quite different, particularly in southern Europe.

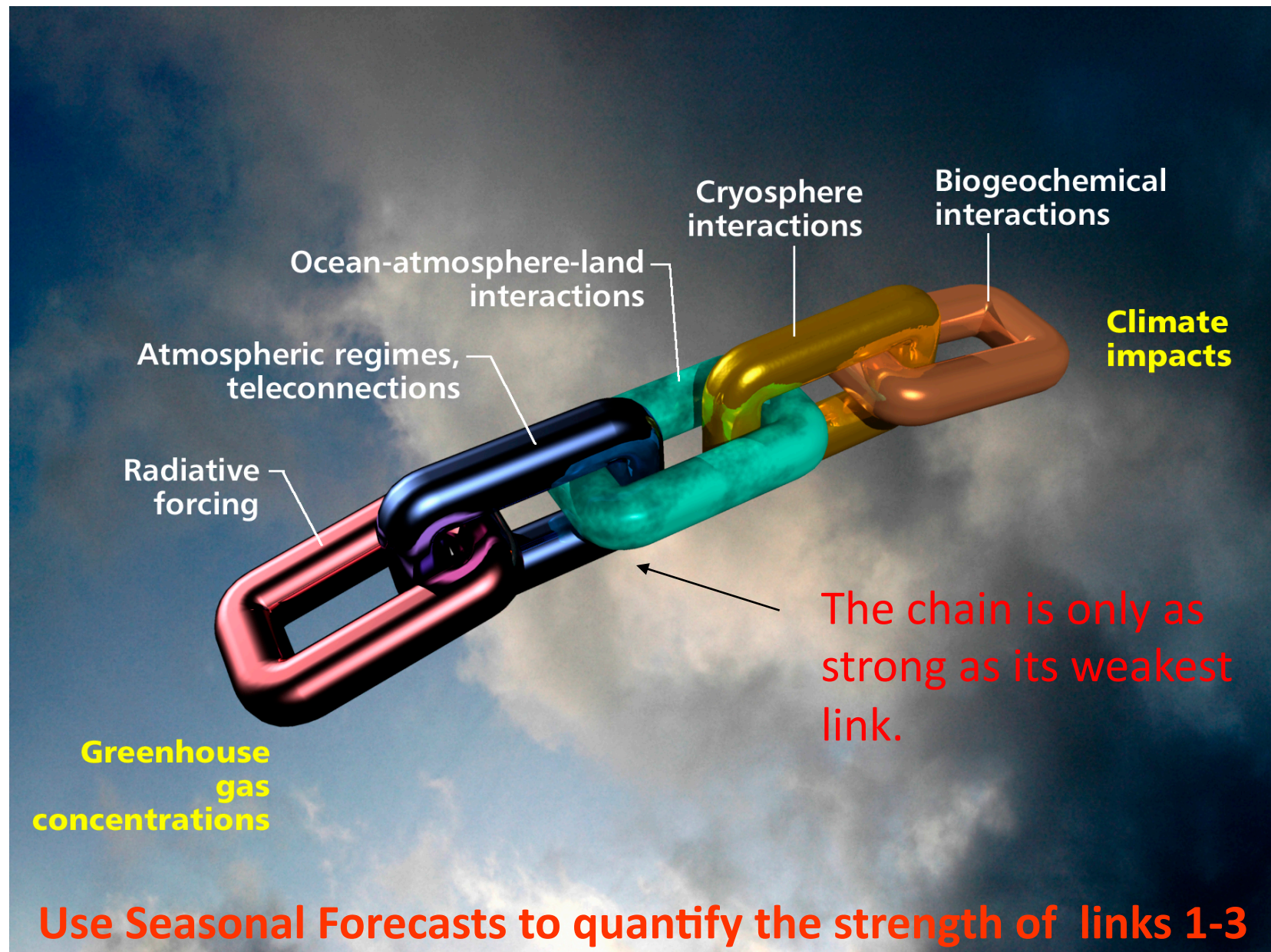
Research Issues

- Earth system model development
- Process-resolving model development
 - Regional domain models vs. global models (mesh refinement)
- Model bias reduction
- Uncertainty quantification
- Data assimilation for non-atmospheric components
- Earth system reanalysis
 - Salinity (under-constrained prior to Argo floats)
 - Global soil wetness (highly variable observing system)
 - Mass, extent, thickness and state of sea ice, snow
 - Atmospheric composition (GHG, aerosols, etc.) and external forcing (solar variability)

Processes & Time Scales

- Climate-relevant processes occur on a wide range of time scales
 - Seconds: Formation of cloud droplets and cloud ice crystals
 - Hours: Mesoscale circulations in atmosphere
 - Weeks: Monsoon circulations
 - Seasons: El Niño and its impacts
 - Decades: Basin-scale ocean circulation
 - Centuries: Continental-scale ice sheet growth and decay
- Highly interactive across time scales
 - E.g., Cloud droplet characteristics, influenced by convective circulation and atmospheric composition, help determine planetary albedo → energy balance → long-term climate and response to increasing GHG
 - Climate and weather share many of the same underlying physical and chemical processes
- All of the above suggests a more unified modeling approach

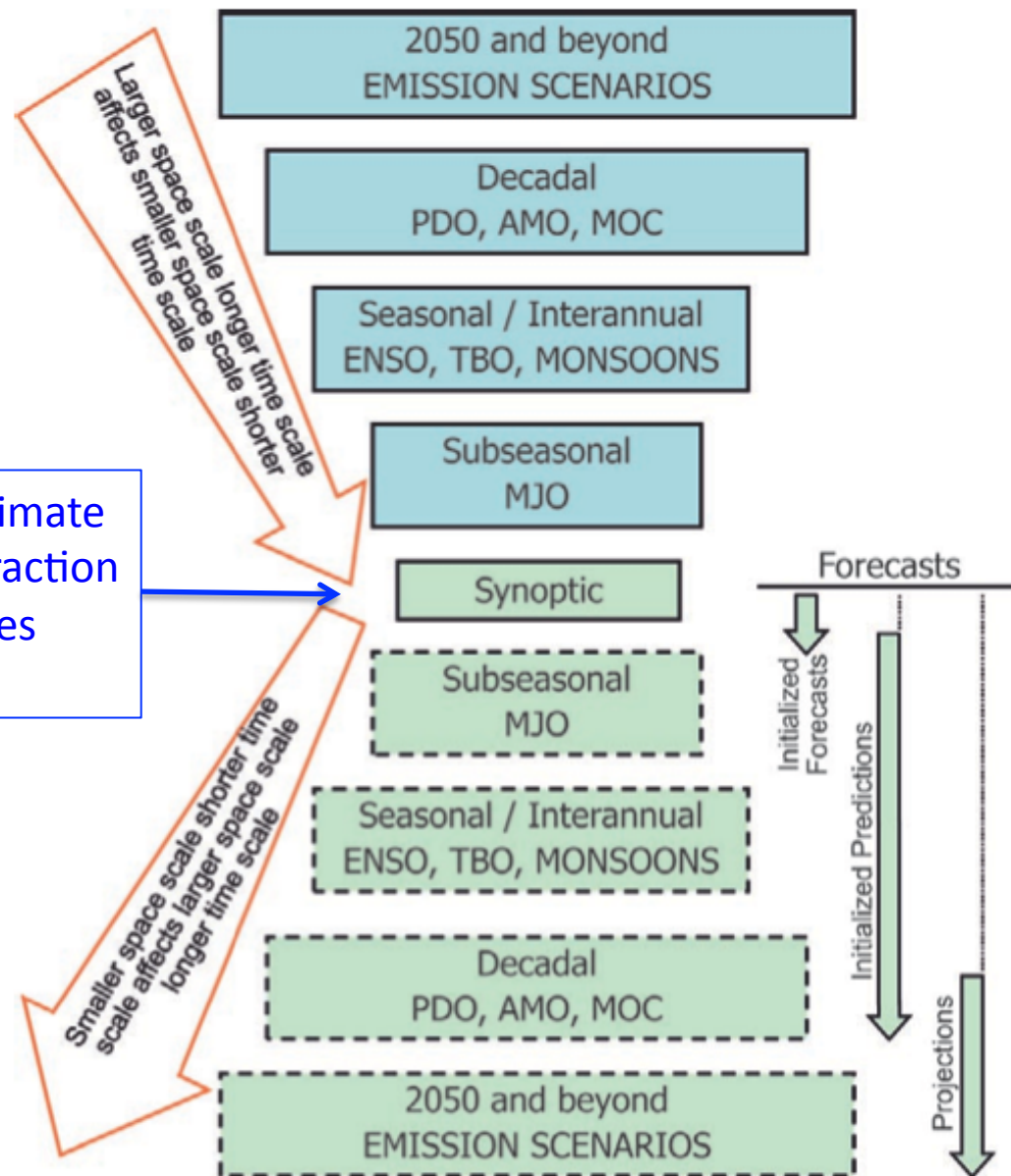




Time and Space Scales

Critical (fast) processes in weather and climate

- Cloud – aerosols – radiation interaction
- Diapycnal mixing of oceanic eddies
- Land surface – PBL interaction



Hurrell et al. 2009

“Seamless” Approaches

- “*Strong*” *seamlessness*: a unified modeling approach in which the same model code, with different grids and/or parameter settings, is used for severe weather prediction, medium-range weather prediction, ISI climate prediction and global change projections
- *Palmer*: Using the constraints and insights gained from NWP to influence climate model development and the climate prediction enterprise
 - Can reduce long-standing uncertainties in climate effects of cloud-aerosol-radiation interaction, other fast processes
- *Brunet, Hurrell*: Data assimilation for coupled models as a prediction and validation tool for weather and climate research
- Running NWP models at ISI time scales
- Running IPCC-class models to predict days to decades
- Focusing climate model development on fast processes

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Initial Value Problem
Data Assimilation
Initialization

NWP to
prediction
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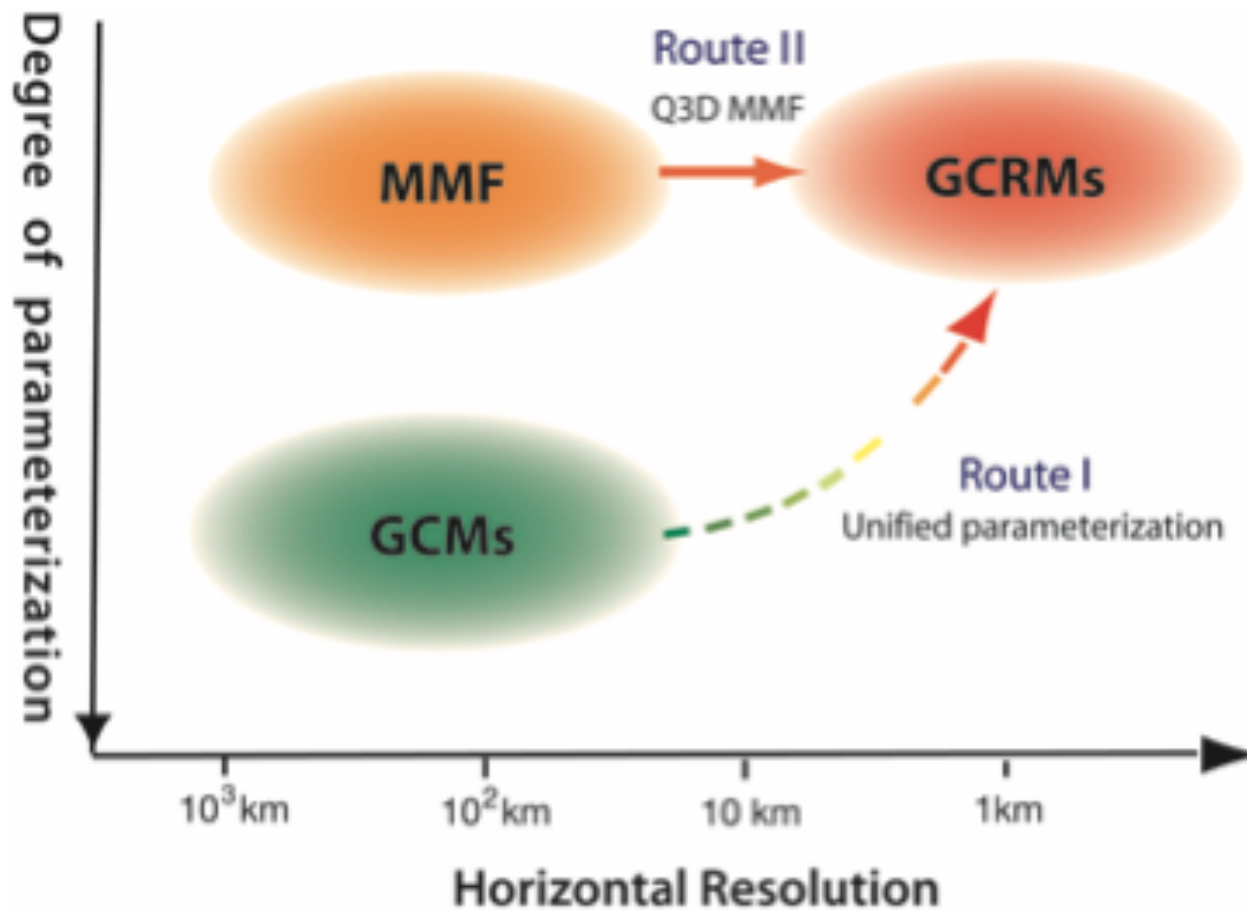
Computing

- Computational capability has increased $> 10^6$ X since 1970s – what have we done with that resource?
- In weather prediction:
 - Increased spatial resolution ~ 20 X (8000 X in CPU)
 - Increased ensemble size 10-50 X
 - Increased sophistication of parameterizations (~ 2 X in CPU)
- In climate simulation:
 - Increased spatial resolution 4 X (64 X in CPU)
 - Increased ensemble *and scenario* size 10 X
 - Increased model *complexity* (components) 2-4 X
 - Increased model *integration time* 500 X

Climate Prediction Goals

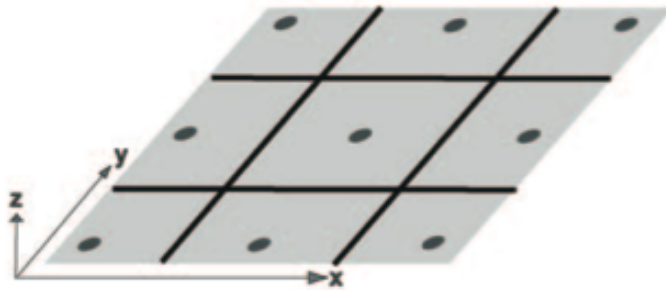
- “*Perfect*” model: A climate model based on first principles that reproduces the observed climatological statistics
 - Requires evaluation and improvement of process parameterizations and component interactions

Cloud Processes

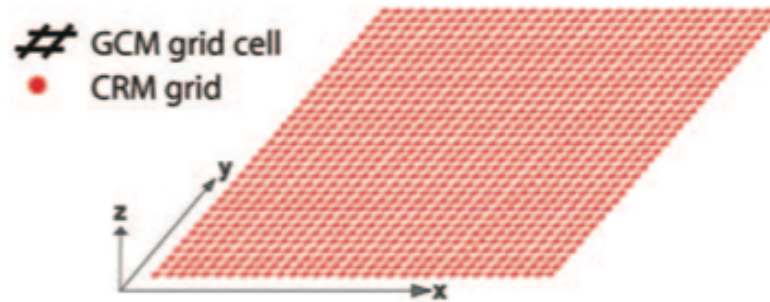


Arakawa et al. 2011

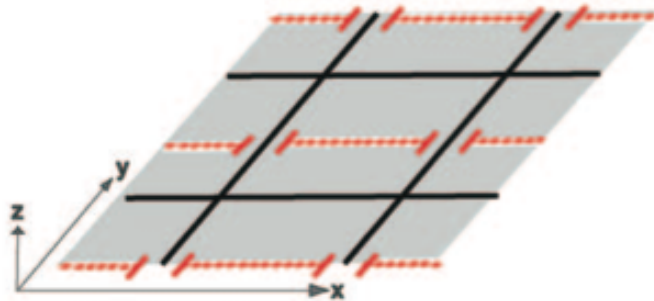
(a) Conventional GCM



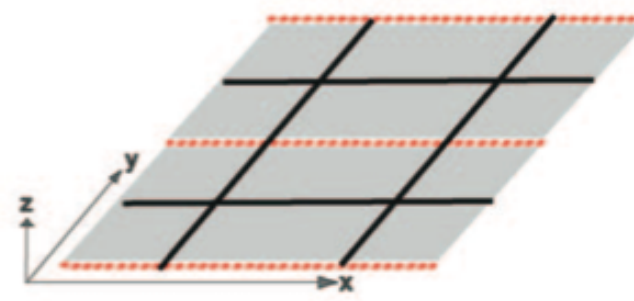
(b) 3D CRM



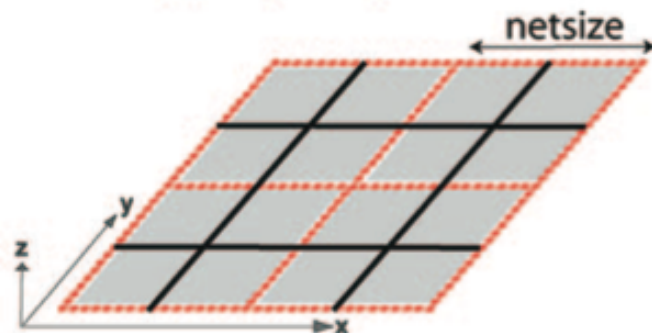
(c) Embedded 2D MMF



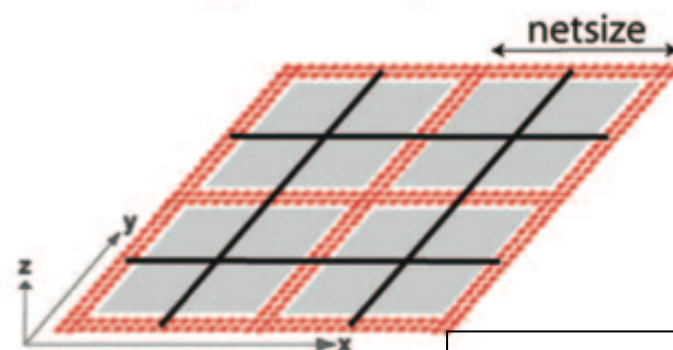
(d) Extended 2D MMF



(e) Original Q3D MMF



(f) Current Q3D MMF

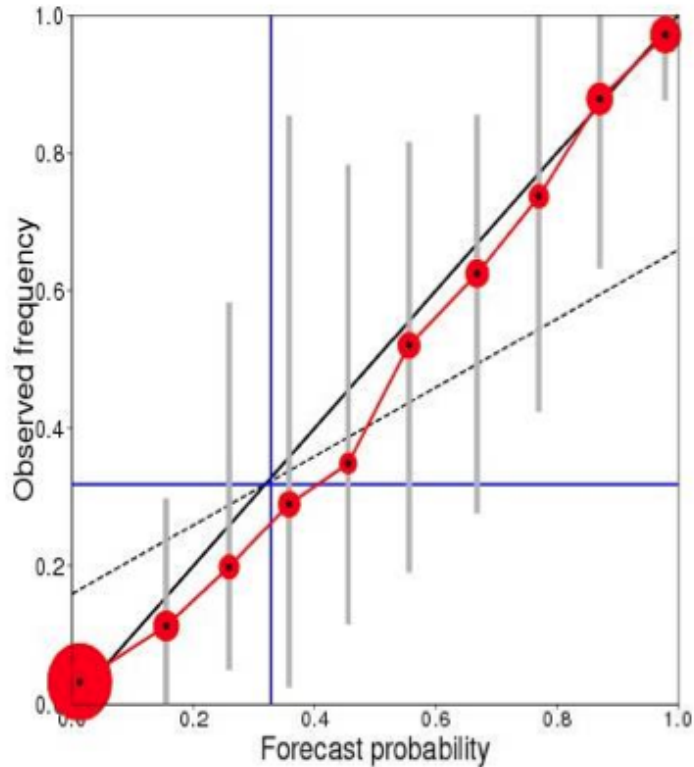


Jung et al. 2011

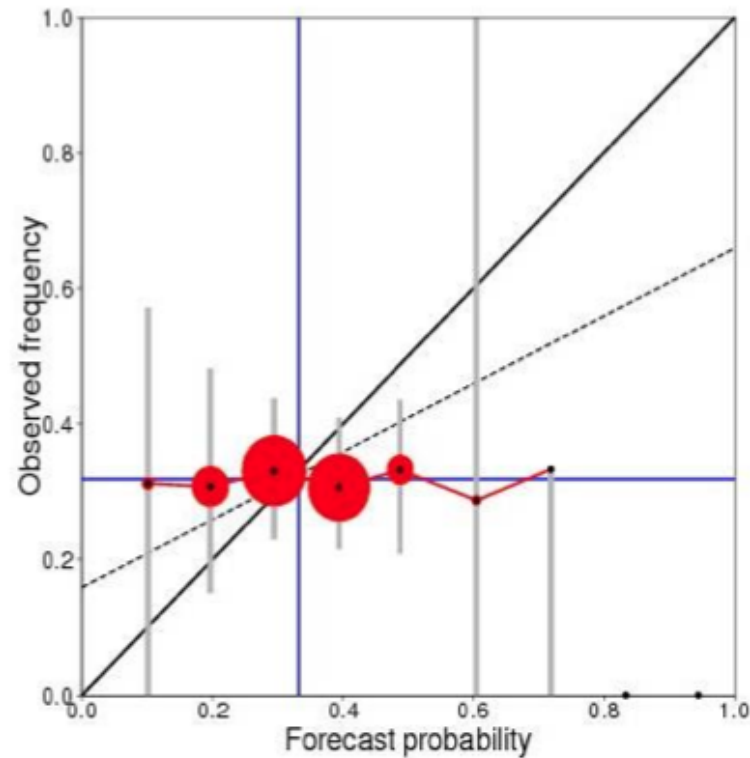
Climate Prediction Goals

- *“Perfect” model*: A climate model based on first principles that reproduces the observed climatological statistics
- *Realistic, reliable probabilities*: Reduce the inherent uncertainty in the (probabilistic) climate prediction problem to its irreducible minimum

MME - Reliability?



NINO3 T2m



Europe Precip

ENSEMBLES MME (45 members)

Climate Prediction Goals

- *“Perfect” model*: A climate model based on first principles that reproduces the observed climatological statistics
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 - Transition: Research to Operations (across “valley of death”)

Climate Prediction Goals

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 - Transition: Research to Operations (across “valley of death”)
- *Status quo*: Climate models have diverged, being developed separately at several different (US) institutions
 - Competition among institutions (probably good)
 - Each institution developing everything (probably each is sub-critical)
 - Opportunity to estimate uncertainty using multi-model ensembles (non-optimal – need **purposeful** ensemble)

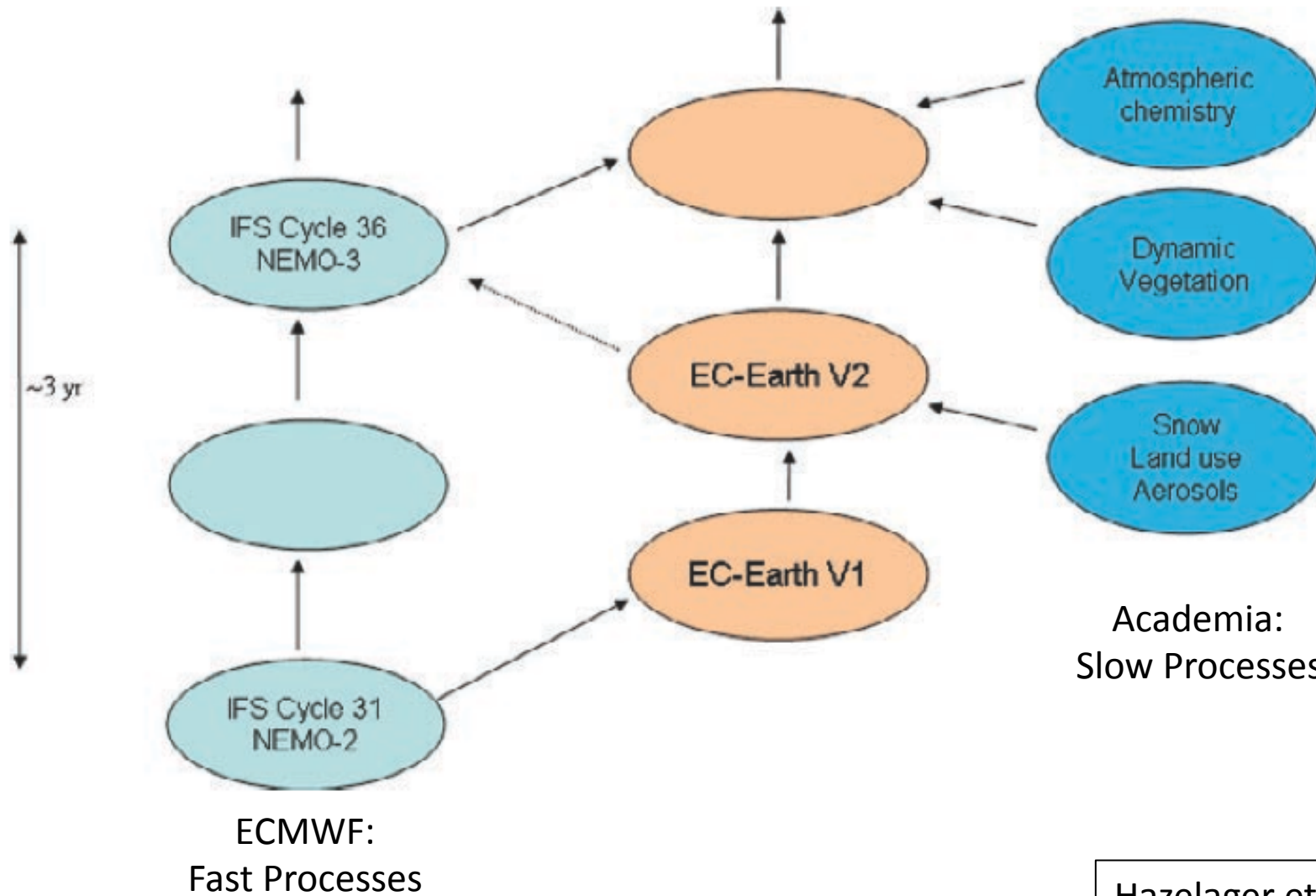
Is this the best path toward the goals above??

Multi-National Approach

- International center (a la CERN) with ~3 inter-connected multi-national computing and prediction nodes to develop most advanced climate model
- Connection to national centers providing regional climate predictions and adaptation research centers providing value-added interpretation of predictions
- Benefits:
 - Reliable quantitative predictions of regional climate change.
 - Support for cost-effective adaptation and mitigation strategies.
 - Universal free access to the most accurate and reliable predictions from 3-model ensemble.
 - Improved global capacity.
 - Computational capability unavailable at national level.
 - Fundamental advances in climate modeling and prediction.

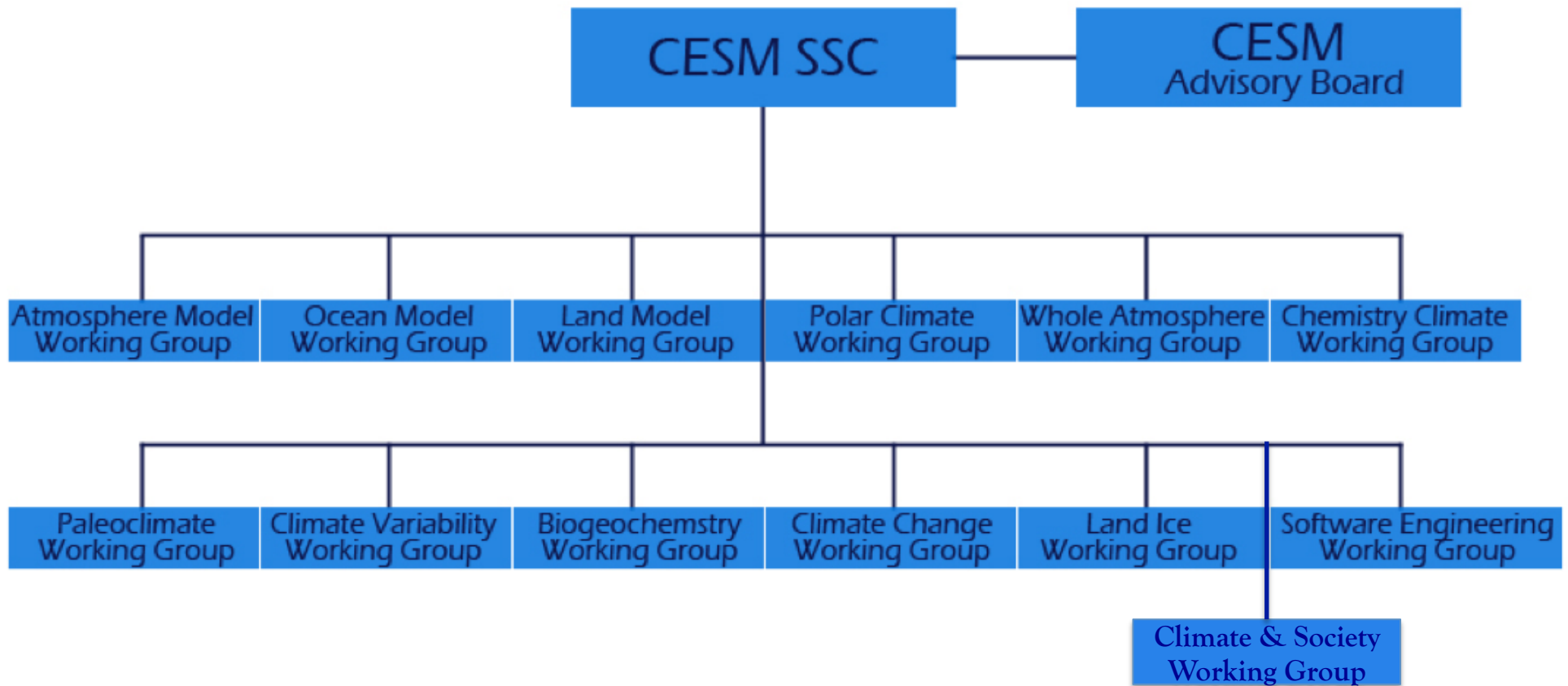
WCRP 2005
Shukla et al. 2010

EC-Earth Strategy

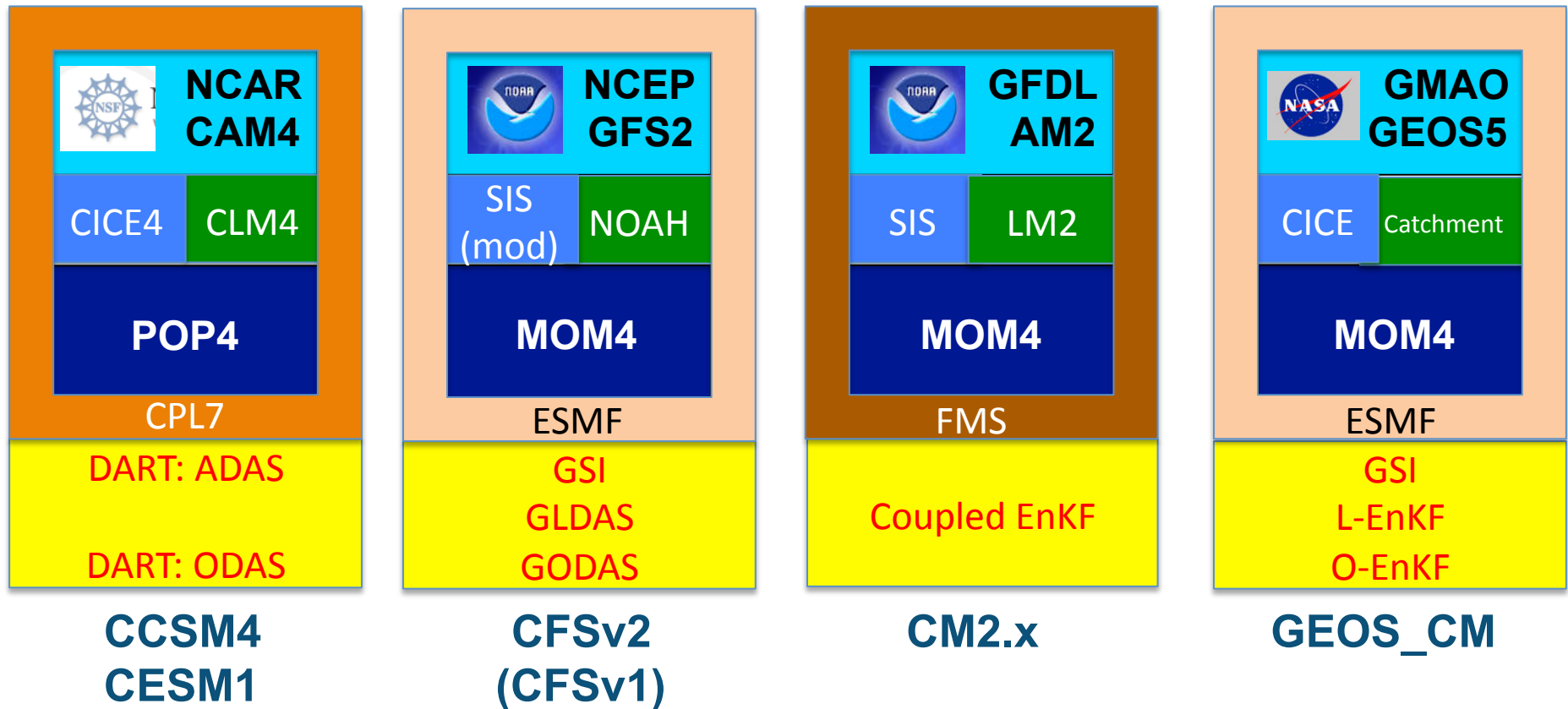


Hazelager et al. 2010

CESM – A Community Approach

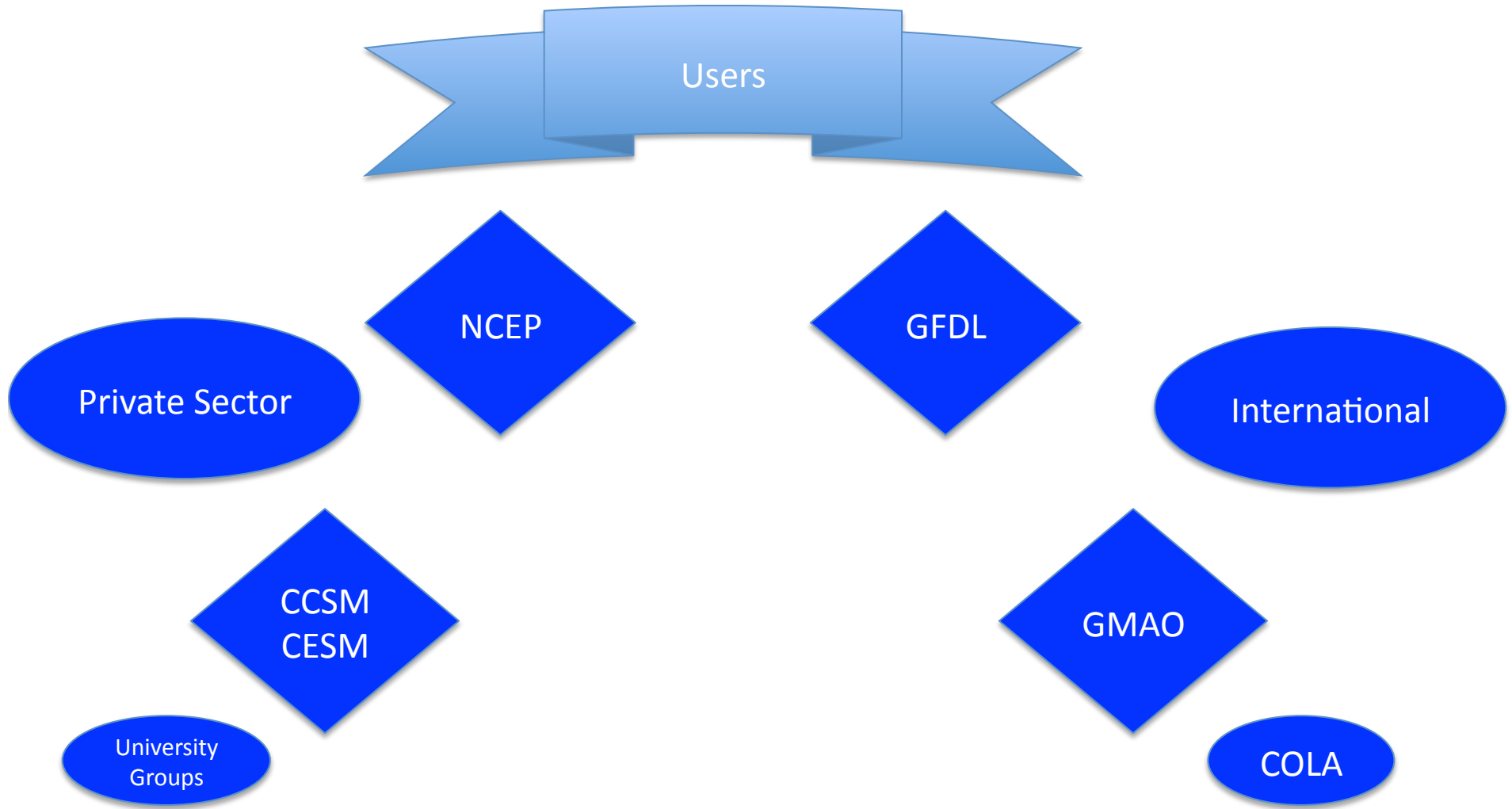


Model Development at National Labs



Note: "National labs" = critical-mass model development efforts of at least 2 in-house model components. GCM-based predictions are also made by COLA (CCSM, CFS), IRI (ECHAM4.5+MOM3), Scripps (GSM+MITgcm), and U. Miami (CCSM).

Framework



Framework

